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Surface storage is to the term for the use of man-made, above-ground reservoirs to collect water for later release when needed. Surface storage has played a key role in California where the quantity, timing, and location of water demand frequently does not match the natural water supply availability. Many California water agencies rely on surface storage as a part of their water distribution systems. In addition, reservoirs also play an important role in flood control and hydropower generation throughout California.

In addition, surface storage is often necessary for, or can increase the benefits from, other water management strategies such as water transfers, conjunctive water management and conveyance improvements. Some reservoirs contribute to water deliveries across several regions of the state while others provide only relatively local water deliveries. There are two general categories of surface storage reservoirs: (1) those formed by damming an active, natural river and (2) those called off-stream reservoirs which require a man-made diversion or pumping of water from a river into storage.

Additional surface storage benefits can be developed by enlarging a dam and the water it stores behind it, reoperating the releases from a dam (see Chapter 6 System Reoperation) or modifying existing reservoirs. Smaller reservoirs typically store water only annually in the winter for supply use in summer, while larger reservoirs hold extra water over several years (known as carryover storage) as a reserve for droughts or other emergency supplies. In recent decades, reservoir operations have been most affected by the need to meet environmental regulations for the protection of impacted fish species. Today multiple purpose surface storage projects balancing water supply, flood protection, hydropower production, water quality and ecosystem needs are the norm.

The information in this chapter focuses on regional and local surface storage alternatives, but does not include the major surface storage investigations of the State and federal CALFED program, which are described separately in Chapter 12 Surface Storage – CALFED.

Surface Storage in California

California has nearly 200 surface storage reservoirs greater than 10,000 acre-feet with a combined storage capacity of more than 41 million acre-feet. These are tabulated in chronological order within Update 2009 Volume 4 Reference Guide section on Infrastructure. In addition, there are many more reservoirs smaller than 10,000 acre-feet that are used to provide for a wide range of water uses, such as stabilizing water delivery to customers or providing a backup supply for emergency needs.

Most of California's reservoirs were constructed more than 40 years ago; the number of new reservoirs built has steadily declined since the 1960s. Only six new water supply reservoirs were constructed in California in the 1980s and 1990s, while only three have been completed since 2000. Examples of recently completed surface storage projects servicing local or regional areas include the US Bureau of Reclamation's Warren H. Brock Reservoir located on the north side of the All American Canal in

Imperial County in 2010; Olivenhain Reservoir in 2003 by San Diego County Water Authority; Diamond Valley Reservoir in 2000 by Metropolitan Water District of Southern California; Seven Oaks Reservoir by the US Corps of Engineers and Orange County Flood Control District in 1999; and Contra Costa Water District's Los Vaqueros Reservoir in 1998. The primary benefits of these new reservoirs include water supply reliability against catastrophic events and droughts; operational flexibility to meet peak summer water demands; water quality improvement; flood control; hydropower and capturing excess flows.

A few enlargements of existing surface storage reservoirs have been completed since 2000 to meet anticipated future needs. Examples include the 60,000 acre-feet expansion of Los Vaqueros Reservoir by Contra Costa Water District scheduled for completion in 2012; the 24,000 acre-feet expansion of Topaz Lake Reservoir on the California/Nevada border in 2008 to increase flood control; the 152,000 acre-feet enlargement of San Vicente Reservoir in San Diego County in 2006; and the 42,000 acre-feet expansion of Lake Kaweah reservoir in 2004 for flood protection and agricultural water supply.

[The ACWA survey results could be included here.]

Some surface storage has decreased across the state due to the removal of smaller, older, obsolete dams, primarily for the purpose of improving fish habitat and passage upstream. DWR's Fish Passage Improvement Program in the FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO) maintains a list of dams removed for fish passage purposes. Their Bulletin 250 and other reports describe past and current structures removed to improve fish passage in California. One of the reasons that removal of these existing dams is feasible is that newer more efficient alternatives now serve the projects original purposes for water deliveries or hydropower generation. In early 2010 a package of agreements was signed between many local stakeholder groups, three tribes, PacifiCorp, California, Oregon and the federal government which is leading to the removal of four hydroelectric dams on the Klamath River in Oregon and California. The removal will improve fish passage and possibly bring about a major fisheries restoration.

Over the past three decades new regulations and legislation have required many reservoirs to be operated in a more environmental friendly manner to improve downstream riverine habitats and fisheries. Specifically, many existing reservoirs have been re-operated to achieve ecosystem and river recreation benefits beyond the original project objectives.

As the competing water demands for agricultural, urban, and environmental needs have grown, the operational flexibility of California's various surface water systems has decreased. Today's water system managers face a complex array of competing demands on the use of limited reservoir storage, which potentially results in more water reductions during droughts.

The relative need for additional local surface storage development may be greatest in the state's interior mountainous areas such as the Cascades and the Sierra Nevada. Although much of the water used throughout the state originates in the mountains, these locations generally possess limited groundwater supplies, are particularly vulnerable to the impacts of climate change on hydrology, and have a shorter list of water management strategies available to meet local needs. This is largely due to geographic, hydrogeologic or hydrologic limitations. Of these few strategies, new surface storage or enlargement of existing reservoir storage may hold the greatest potential for achieving local supply reliability objectives.

Local surface storage development options could also include the reoperation of existing reservoirs through the development of water sharing or purchasing agreements with the downstream owners of existing reservoirs.

Potential Benefits of Surface Storage

Many of California's reservoirs were originally built for one or two primary purposes such as agricultural and municipal consumptive water use, flood control and hydropower. However, over time the number of benefits asked of surface storage has generally expanded to also include the following:

- Water quality management
- Ecosystem management
- Sediment transport management
- River and lake recreation
- Emergency water supply
- System operational flexibility

The presence of new surface storage allows water managers the flexibility to implement water management strategies more easily and more efficiently or to implement strategies simply not available without storage. Storage helps solve the temporal problem that occurs when the availability of water and the demand don't occur at the same time. Often regional conservation efforts are ineffective if the water conserved can't be stored for later use. Storage allows water transfers between regions to occur at any time, not just when the water is needed for immediate use. In addition, water transfers early in the water year are generally less expensive due to less demand than transfers later in the water year. Surface storage is needed to enable and improve the effectiveness of conjunctive water management strategies by controlling the timing and volume of water ultimately conveyed for storage in groundwater basins.

Dealing with climate change impacts is a key concern for California's water purveyors. Climate change projections foresee more extreme weather such as floods and droughts. More importantly, warming temperatures will raise the snowfall elevation causing more winter precipitation in the Sierra Nevada to occur as rainfall and create larger and earlier runoff events. In addition, several million acre feet of natural snow pack storage could be lost. By expanding surface storage capacity, water supply systems will have greater flexibility to capture the increased winter runoff and help control larger anticipated flood flows. Additional reserve storage would also allow water to be held over for all uses in dry years and droughts.

Potential Costs of Surface Storage

Cost estimates for potential surface storage alternatives are not specified in this narrative because they vary extensively by region and specific project design. In most cases, the costs of multipurpose storage projects are shared by many beneficiaries and often include a State or federal cost-share component. The magnitude of individual project benefits and corresponding costs for new water supply, hydropower, flood management and water quality, as examples, can be expected to vary significantly from project to project such that average cost information is not accurate.

Major Issues Facing Surface Storage

Climate Change

The anticipated impacts from climate change could greatly influence water management in California. Surface storage provides both adaptation (preparation for unavoidable changes) as well as mitigation (reduction of overall impacts) benefits in relation to climate change. As discussed above, warming temperatures will raise the snowfall elevations resulting in more winter precipitation occurring as rain, increasing winter runoff. This shift in runoff timing limits the ability to capture water for supplies while still providing adequate flood protection in the reservoirs. Earlier runoff also results in lower stream flows, increased water temperatures and reduced water quality in the summer and fall.

Adaptation

Increasing local and regional surface storage has the potential to provide greater flexibility for capturing runoff and managing supplies to meet varied future water demands, provide a buffer during dry years and droughts, and reduce flood risks. With more precipitation occurring as rain the mountainous regions will experience less groundwater recharge as winter runoff increases. The use of surface storage can capture a portion of this water, increasing in the local water supplies and reducing downstream flood risks. For regions relying on surface water, increasing local surface storage, will allow for more transfers during wet years for storage until needed during dry years and droughts, increasing regional resiliency.

Mitigation

Energy intensity of surface storage could be different depending on the net energy input or energy used for construction and maintenance. Better managing and increasing local surface storage with relative lower energy intensity by strategies discussed in the chapter could provide benefits to reduce energy use and Greenhouse Gas (GHG) emissions from the higher energy- intensive water project operation.

1. Adaptively managing operations of existing facilities and increasing efficiency and flexibility in response to system complexities and climate change could save more energy and reduce related GHG emissions.
2. Evaluating benefits and impacts of water and energy as well as full costs in regional/local surface storage project planning could select and evaluate project options with criteria beneficial for climate change mitigation.
3. Upgrading existing surface storage projects with rehabilitation and enlargement of existing dams and infrastructure before developing new storage projects could reduce energy use and GHG emissions from the new projects. Upgrading existing projects may use less energy than that from constructing new projects.
4. Developing interagency agreements to buy water from agencies that own storage reservoirs and evaluating option of conjunctive surface storage with groundwater management could provide alternatives for possible benefits to reduce energy use and GHG emissions from new storage projects.
5. Coordination of IRWM agencies on regional storage projects could provide energy and system efficiency with operation criteria and watershed water quality control, which have energy saving potential for GHG emissions reduction.

Funding and Identifying Project Beneficiaries

Construction usually requires a substantial amount of money in a short time – several to hundreds of millions of dollars. Included in the long-term capital outlay are planning costs such as administrative, engineering, legal, financing, permitting and mitigation. Some new storage options, such as raising existing reservoirs, reoperating them, or constructing small local reservoirs, may require significantly less capital, but may require local funding through revenue or general obligation bonds.

There are concerns related to how the beneficiaries will be determined, who will actually pay and who will control the storage operation. One financing concept assumes that only the direct beneficiaries of a proposed storage project should pay for the construction and operation costs. However, many of the beneficiary groups do not have adequate financial resources to build large projects without outside financial assistance.

Another general financing concept relies on a large percentage of State and federal funding support to assist in the construction of new projects. When this method is proposed, the project beneficiaries will have a smaller, more affordable project cost component to fund. However, the process of obtaining funding approval from either federal or State government agencies generally requires substantially more time and justification documents. The challenge is to develop financial and operations agreements that have the best possibility for successful allocation of project costs corresponding directly to the beneficiaries and uses of a given project.

Impacts

New storage can affect environmental and human conditions and can create economic impacts for the surrounding community and flow impacts both up and downstream of diversions. New reservoirs may result in the loss of property tax revenue to local governments in the area where they are located due to inundated developed land or land suitable for development or result in an increase of local property values by firming up a water supply. Regulatory and permitting requirements require surface storage investigations to consider potential impacts to streamflow regimes, potential adverse effects on designated wild and scenic rivers, potential water quality issues, potential changes in stream geomorphology, loss of fish and wildlife habitat and risk of failure during seismic or operational events. Existing environmental laws require that these effects be addressed and potentially mitigated. Mitigation of environmental effects is normally accomplished through implementation strategies that avoid, minimize, rectify, reduce over time, or compensate for negative impacts. New surface storage projects are required to address impacts under the application of various laws, regulatory processes and statutes such as Public Trust Doctrine, State dam safety standards, Area of Origin statutes, California Environmental Quality Act, National Environmental Policy Act, the Clean Water Act and the Endangered Species Acts (state and federal).

Suitable Sites

Most of the best natural reservoir sites in California have already been developed and environmental regulations and mitigation requirements impose significant constraints on development of new surface storage in California's mountainous areas. In some areas, the development of new offstream storage is a feasible alternative if the geographic terrain provides suitable locations. Another option which has received consideration in recent years is the rehabilitation and enlargement of existing reservoirs. This has

the advantage of using an established reservoir site, but the feasibility and costs for rehabilitation of an older facility must be carefully evaluated.

Project Funding

The range of surface storage development options is generally more limited for smaller local agencies than for the State and federal governments, because limited agency funding and staff resources impact their capability to complete complex feasibility studies, design documents, environmental impact studies, and related project planning needs. These circumstances severely constrain the ability of local governments and agencies to finance and implement the projects necessary to sustain the local economy, preserve or restore riparian habitats and provide water supplies for regional population growth. Traditionally small local agencies have been unwilling to fund projects outside their service areas. However, recently local partnerships through Integrated Regional Water Management Plans have pooled resources and collaborated on local shared storage projects aimed at benefiting all regional participants.

Recommendations to Better Manage and Increase Surface Storage Benefits

1. Local agencies seeking to implement storage projects should develop a comprehensive methodology for analyzing all project benefits and costs. The California Department of Water Resources should provide guidance, technical expertise and planning process assistance to local agencies if requested.
2. Reservoir operators and stakeholders should continue to adaptively manage operations of existing facilities in response to increased understanding of system complexities and demands as well as changes in natural and human considerations such as social values, hydrology, and climate change.
3. The Department of Water Resources and other State, federal and local resource management agencies should continue studies, research, and dialogue focused on a common set of tools that would help determine the full range of benefits and impacts as well as the costs and complexities of surface storage projects.
4. Water resources scientists, engineers, and planners, including DWR, should recognize the potential long development time required for new surface storage in securing funding needed for continuity of planning, environmental studies, permitting, design, construction, and operation and maintenance.
5. Rehabilitation and possible enlargement of existing older dams and infrastructure should be given full consideration as an alternative to new reservoir storage.
6. As an alternative to new storage, agencies should consider the potential to develop water purchasing agreements to buy water from other agencies that own storage reservoirs with substantial water supplies.
7. Investigate integrating existing surface storage with groundwater management and/or other water supply options (e.g., water use efficiency).
8. Team with other regional agencies through the IRWM plan process on new regional storage projects.
9. Surface storage can be the center piece of a comprehensive IRWMP offering multiple benefits and the flexibility to fully implement many other RMS's. Shared local or regional surface

storage can enhance water user ability to implement conjunctive groundwater storage, integrate flood management practices, take full advantage of water transfers, assist in ecosystem restoration and offer recreation benefits--all by augmenting consumptive water use.

Regional/Local Surface Storage in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions aren't consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn't discussed in the rest of Update 2013), there is no need for this section to appear.]

References

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Additional References

Personal Communications